

The Identification and Evaluation on the Risk Sources of Grid Electricity Purchasing

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Abstract

This paper analyzes various types of risk sources in the process of Grid Company to purchase electricity, in reaction to which comprehensive evaluation system has been developed in this paper. Based on combination method and fuzzy comprehensive evaluation method, the Grid Company risk empowerment evaluation indexes and the comprehensive evaluation method have been established, aiming at providing decision-making support for the risk study on purchasing power of Grid Company' and implementation of comprehensive evaluation.

Keywords

Power Purchasing Risk; Risk Identification; Risk Evaluation

Introduction

With the further development of China's power market reform, the traditional vertically integrated monopoly is completely broken; and the Grid Company becomes an economic entity independent of the power generation company, and confronts diverse risk derived from different market participants. Due to the complicated factors that bring risk in the electricity purchasing and selling process, such as the fluctuations on policy resulting from electricity market reform, on both the demand and supply side, as well as on the trading rule, and changes on the feed-in tariff, the operation and management system, and power technological innovation and other policy, therefore, it is necessary to identify and evaluate the risk sources.

Most of studies on the risk management of the Grid Company focus the risks that the Grid Corporation may face in electricity market environment. For example, papers[1-2] respectively study risk from large consumers' direct purchase of electricity and options trading. There are many research methods for risk identification. Papers [3-4] respectively research the use of portfolio theory and risk profits constraints

on grid power purchase risk analysis. However, these studies and analyses mainly put emphasis on an aspect or a part of the risk analysis, and it is difficult to effectively identify all kinds of complicated risk in the process of the Grid Company to buy electricity. Thus, this paper makes a practical and significant evaluation on classified purchase risk source Grid Company confronts.

Risk Sources Identification Of Electricity Purchasing

The risk the State Grid Company confront when purchasing electricity comes from different markets participants. For the convenience of effective management of Grid Company's operation, risk can be classified according to the sources of risk. After the power market of the supply side preliminarily forms, the main risk the State Grid Company (SGC) faces can usually be divided into: risk from demand side, supply side, or SGC and the government side.

Risk from Demand Side

The SGC buy electricity from power suppliers, and then sell to power users. Risk from demand side is due to the uncertainty that SGC faces in the selling process to customers, including risk of conventional load forecasting error, risk of direct power purchase of heavy buyers, risk of the self-provided power plant, risk of alternative energy, etc.

1) Risk of Conventional Load Forecasting Error

The SGC usually makes electricity purchasing strategy according to the load forecasting error in the aspect would bring market risk for SGC. If the forecast is too low, it could lead to load shedding or reduction of the benefits from selling electricity to the adjacent areas; otherwise, a part of the power bought by the SGC can't send out, or they have to

pay liquidated damages to the producer, which will also affect SGC's income.

2) Risk of Direct Power Purchase Of heavy Buyers from the Generation Companies

The direct purchase of electricity conduct will change the operation mode of current power market; and the SGC will also generate electricity purchasing cost, change the income from selling electricity and entrust transmission service, and etc. The combined effect of the last two is the main reason for the changes in the SGC income. If the distribution electricity price of direct purchase is higher than the original enterprise profit space, then the direct purchase can increase the SGC's overall operating profit; otherwise, it will decrease.

3) Risk of the Self-provided Power Plant

The investment of self-provided power plant may directly result in the decrease in power sold to heavy buyers enterprise that has self-provided power plant, even as the tide of "zero". Namely, the power supply circuit construction for the enterprise becomes "sunk cost" without economic benefits, and the power sale quantity is zero unable to get main business income from these enterprises.

4) Risk of Alternative Energy

Risk of alternative energy is the change of electricity purchasing price caused by alternative energy price changes, such as oil, coal and natural gas prices. On one hand, the lower or higher of alternative energy prices will change the SGC's power purchase demand accordingly; on the other hand, the rise in oil prices leads to the increasing electric car demand that causes the rise of power demand. These two aspects make the SGC purchasing power fluctuated, and increase the difficulty of load forecasting and the operational risk.

Risk from Power Supply Side

SGC may face the risk from power supply side in the process of buying power from the generators, such as the power supply situation in the province, fluctuation of electric price, cross-province and cross-district trade, etc.

1) Risk of Power Supply in Province

Since the condition of power differs much from one province to another in our nation, the power structure and the installed capacity are different

among provinces, which leads to the instability of power and frequency in the generation process. In addition, the purchase amount of electricity is limited, which leads to the low-quality and uncertainty of power.

2) Risk of Fluctuation of Electric Price In Province

The electric power purchased by the grid mainly contains thermal power, hydropower, nuclear power and new energy power. The power generation technology, operating cost, tax policy and policy of the power industry may change, resulting in the fluctuation of online price. This may directly influence the purchase price of the SGC, thus increasing the buying cost of electricity and risk of the trade.

3) Risk of Cross-district and Cross-province Supply

To achieve the optimize configuration of the electric market resources, and to pursue the maximum profit of the grid through trade and cooperation, the cross-district and cross-province trade appear. However, the stability of power in other provinces, the transmission of electric power and the credibility of generating company from other provinces could incur some risk. Increasing the amount of power purchased from other provinces means the rise of long-distance power transmission, the increase of the transmission line load, of network loss, which may urge the grid to buy more power from others to fill the network loss and the power demand, and increase the buying cost of power at the same time.

Risk from SGC Side

When the power trade continues, the risk both exist on the supply and demand side, and the congestion risk of transmission, the technology risk brought by the network stability, the risk of trade management could also influence the result.

1) Risk of the Transmission Line Congestion

The transmission line congestion means that the security and stability of the network may be threatened by the limitation of the transmission capacity, because the line capacity could not meet the demand of all the trades, thus causing that the power trade could not develop smoothly as planned, and may influence the SGC's profit. Besides, this congestion may influence the security of the grid to a certain degree.

2) Risk of the Network Stability Technology

Because of the peak shaving constraints and the transmission technology constraints, the overload of the line, the damage of the instruments and the fluctuation of the amount emerge, which may lead to the power failure or power rationing in some districts, resulting in economic and credibility loss to SGC. In addition, the addition of the renewable energy to the grid and policy of energy saving could all affect the technological stability of peak shaving of the grid and thus bringing threat to the grid.

3) Risk of Trade Management

Risk of trade management means that the increase of SGC power purchasing risk caused by the auction mechanism, settlement rules, generators' bidding strategies, process management of the contract and electricity purchasing process management in the electricity market. These factors involving in each step of the electricity transaction, could directly or indirectly influence the electricity purchasing strategy and plan of the SGC through the affect made on the behaviors of generators, grid and customers.

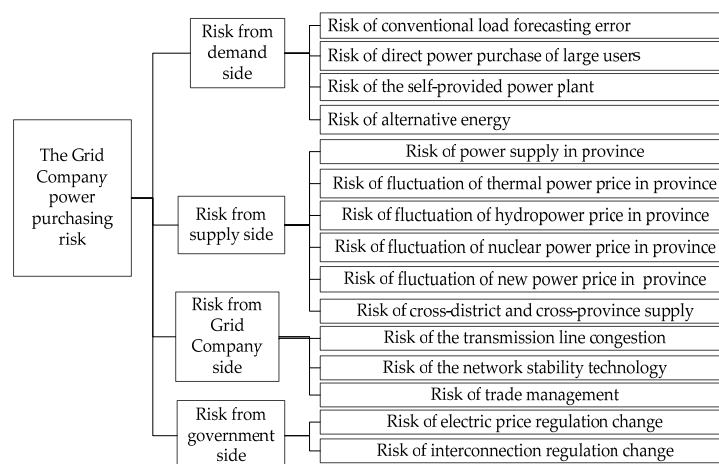
Risk from Government Side

The SGC should abide by the regulation on electricity price while buying electricity, otherwise the stability and security of the SGC will be threatened if the government changes the established policy or the electric industry law.

In China, the online and selling price of the electricity are influenced significantly by the policy of the government, which leads to the unfairness between buyers and generators from different provinces. However, the electric market resources are allocated according to the market signal, and the amount of electricity will be tilted to the provinces with higher selling price and bearing ability of the price, causing that these provinces, even the provinces which sell power could only buy little power or even no power during some periods, especially the peak time, and also leading to the risk of controlling policy from the government. In addition, the purchasing electricity policies such as the electric price regulation and interconnection regulation will influence the normal operation of the SGC to some extent.

Through the identification of the risk SGC faces when purchasing power, it can be found that the risk comes from four sides: risk from demand side, supply side, SGC and the government. Based on the principles of independence, feasibility and representative, this paper establishes the evaluation index system which contains four primary indexes and fifteen secondary indexes, shown as figure 1.

FIGURE 1 COMPREHENSIVE EVALUATION SYSTEM OF THE SGC POWER PURCHASING RISK



The SGC Electricity Purchasing Risk Assessment

In order to effectively avoid the risk of purchasing electricity, a scientific and perfect risk assessment system should be set up to figure out the behavior of market participants in time, and provide strong support for the SGC.

A Single Risk Source Assessment

The SGC's purchasing electricity behavior is affected by the uncertainty of risk event, so the likelihood, time and consequence of the risk should be taken into consideration when evaluation is made. Through the imitation of LEC engineering risk analysis method, this paper puts forward the LTC evaluation method of a single risk source of electricity purchasing, where L is the likelihood of a hazardous event occurring, T represents the continued time, and C indicates the consequences, thus the electricity purchasing risk D can be expressed as the following formula (1):

$$D = L \times T \times C \quad (1)$$

The score values of L, T and C are shown in table 1:

TABLE 1 THE SCORE STANDARD OF SGC POWER PURCHASE RISK

Rating objects	Scores	Degree of risk
L	10	Completely can be expected
	7	Quite often
	5	Not often, but possible
	2	Completely unexpected, less likely
	0.1	Highly unlikely
T	10	Existent forever
	7	Long duration
	5	Last a few months
	2	shorter
	0.5	Last a few days
C	10	Huge losses, irreversible
	7	Large losses, high cost of recovery
	5	Ordinary consequences, can be restored
	2	Smaller losses, low recovery cost
	0.1	Very small losses

The Index Weight Empowerment Method

Through reference to the research of scholars [5] on weighting methods, combination with the feature of purchasing electricity, combined empowerment approach is employed in this paper, in which two methods to empower different indicator levels are utilized.

Since the participants in electricity market influence the degree of risk the SGC confronts in the course of purchasing, the risk avoiding policy put emphasis on different point, therefore, the importance of risk sources, the avoidance possibility and cost should be considered while the first grade indexes are empowered using sequence relations method, namely if the importance of the evaluation index is set to be x_{n-1} and x_n as ratio w_{n-1}/w_n , then other indicators weight is calculated, and the weight of index t can be calculated as follows:

$$w_t = (1 + \sum_{n=2}^t \prod_{s=n}^t r_s)^{-1} \quad (2)$$

Other indicators' weights are:

$$w_{n-1} = r_{n-1} w_n \quad (3)$$

Since Eigenvalue method is applicable to the secondary index weight empowerment, namely through indexes pair-wise comparison to find out the judgment matrix E , thus the characteristics of the root of E corresponding to the largest eigenvalue are the weights of indicators.

The Power Purchase Risk Comprehensive Evaluation

Since the risk sources of the SGC purchasing power are various and complex, this paper uses expert

scoring method to the secondary index based on the LTC risk score standards, then the fuzzy comprehensive evaluation method is in use.

TABLE 3 THE RESULTS OF SGC POWER PURCHASING RISK EVALUATION

Elements	evaluation results				
	Very large	Large	Normal	Small	Very small
Risk of conventional load forecasting error d_{11}	0	1	2	8	9
Risk of direct power purchase of large users d_{12}	1	2	3	12	2
Risk of the self-provided power plant d_{13}	0	7	3	9	1
Risk of alternative energy d_{14}	0	2	0	8	10
Risk of power supply in province d_{21}	1	3	2	9	5
Risk of fluctuation of thermal power price in province d_{22}	1	3	6	4	6
Risk of fluctuation of hydropower price in province d_{23}	2	4	1	10	3
Risk of fluctuation of nuclear power price in province d_{24}	2	2	0	7	9
Risk of fluctuation of new energy power price in province d_{25}	0	1	2	10	7
Risk of cross-district and cross-province supply d_{26}	1	1	3	7	8
Risk of the transmission line congestion d_{31}	1	4	2	7	6
Risk of the network stability technology d_{32}	0	0	1	11	8
Risk of trade management d_{33}	1	2	4	8	5
Risk of electric price regulation change d_{41}	3	7	2	7	1
Risk of interconnection regulation change d_{42}	3	6	4	5	2

Firstly, establish the factors set $U=\{u_1, u_2, \dots, u_n\}$ and judge set $V=\{v_1, v_2, \dots, v_m\}$, calculate the weight set A , then making the evaluation according to the formula (4) after getting expert grading evaluation matrix R .

$$B = (b_1, b_2, \dots, b_m) = A \circ R = (a_1, a_2, \dots, a_n) \circ \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{bmatrix} \quad (4)$$

where b_j is the membership of evaluation object belonging to the j -th comment V_j , and B is a fuzzy set.

Analysis of an Example

Combined with risk evaluation system on electricity purchasing, this paper takes M provincial SGC for example to carry out an evaluation based on LTC scoring method and fuzzy comprehensive evaluation method.

Basic Data

M Province is located in China's western region with abundant wind power resources and normal average reserves of coal and natural gas, in which the industrial development is rapid, especially the energy-intensive industries.

This paper uses the LTC expert scoring method, and then classifies the results of 20 experts scoring shown in Table 3 according to the risk range, and the classification criteria are shown in Table 2.

TABLE 2 THE CLASSIFICATION CRITERIA OF SGC POWER PURCHASING RESULT

Risk degree	Very large	Large	Normal	Small	Very small
Classification interval	[0.35,1]	[0.15,0.35)	[0.1,0.15)	[0.02,0.1)	[0,0.02)

Index weight calculation

1) The Primary Index Weight Empowerment

Comprehensive consideration is made on the influential degree and avoidance possibility of the SGC power purchasing risk, it can be observed that the relatively important relationships of indices as "Risk from the SGC side $d_3 \succ$ Risk from the demand side $d_1 \succ$ Risk from the supply side $d_2 \succ$ Risk and that from the government side d_4 ". Then the importance degree according to the value reference is quantified, that is the order is from up to down based on the importance: Risk from the SGC side, Risk from the demand side (1.2), Risk from the supply side (1.2), Risk from the government side (1.2), thus the primary index weight of evaluation index system is:

$$A = \{d_1, d_2, d_3, d_4\} = \{0.2683, 0.2235, 0.3219, 0.1863\} \quad (5)$$

2) The Secondary Index Weight Empowerment

Through judgment, 15 secondary indicators' judgment matrix can be obtained, and the weight is shown in Table 4 by the eigenvalue method.

TABLE 4 INDEX WEIGHT OF THE SGC POWER PURCHASING RISK EVALUATION SYSTEM

Serial number	Content	Weight vector
1	Index weight of the risk from demand side	$A_1 = \{0.2794, 0.2135, 0.1839, 0.3232\}$
2	Index weight of the risk from supply side	$A_2 = \{0.1365, 0.2203, 0.1559, 0.2160, 0.1952, 0.0761\}$
3	Index weight of the risk from SGC side	$A_3 = \{0.3216, 0.2680, 0.4103\}$
4	Index weight of the risk from government side	$A_4 = \{0.6, 0.4\}$

Comprehensive Evaluation Process

Through using fuzzy statistics and the dimensionless processing to the data of SGC power purchasing risk score, fuzzy evaluation matrix of the primary index can be acquired:

$$R_1 = \begin{bmatrix} 0 & 0.05 & 0.1 & 0.4 & 0.45 \\ 0.05 & 0.1 & 0.15 & 0.6 & 0.1 \\ 0 & 0.35 & 0.15 & 0.45 & 0.05 \\ 0 & 0.1 & 0 & 0.4 & 0.5 \end{bmatrix} \quad (6)$$

$$R_2 = \begin{bmatrix} 0.05 & 0.15 & 0.1 & 0.45 & 0.25 \\ 0.05 & 0.15 & 0.3 & 0.2 & 0.3 \\ 0.1 & 0.2 & 0.05 & 0.5 & 0.15 \\ 0.1 & 0.1 & 0 & 0.35 & 0.45 \\ 0 & 0.05 & 0.1 & 0.5 & 0.35 \\ 0.05 & 0.05 & 0.15 & 0.35 & 0.4 \end{bmatrix} \quad (7)$$

$$R_3 = \begin{bmatrix} 0.05 & 0.2 & 0.1 & 0.35 & 0.3 \\ 0 & 0 & 0.05 & 0.55 & 0.4 \\ 0.05 & 0.1 & 0.2 & 0.4 & 0.25 \end{bmatrix} \quad (8)$$

$$R_4 = \begin{bmatrix} 0.15 & 0.35 & 0.1 & 0.35 & 0.05 \\ 0.15 & 0.3 & 0.2 & 0.25 & 0.1 \end{bmatrix} \quad (9)$$

This article selects the weighted average operator on the demand side risk, and gets comprehensive evaluation vector of d_1 as B_1 :

$$B_1 = A_1 \circ R_1 = (0.2794, 0.2135, 0.1839, 0.3232) \circ \begin{bmatrix} 0 & 0.05 & 0.1 & 0.4 & 0.45 \\ 0.05 & 0.1 & 0.15 & 0.6 & 0.1 \\ 0 & 0.35 & 0.15 & 0.45 & 0.05 \\ 0 & 0.1 & 0 & 0.4 & 0.5 \end{bmatrix}$$

$$= (0.0107, 0.132, 0.0875, 0.4519, 0.3179) \quad (10)$$

Similarly, other evaluation indexes' fuzzy evaluation values can be calculated as:

$$B_2 = A_2 \circ R_2 = (0.0588, 0.1199, 0.1185, 0.3833, 0.3196) \quad (11)$$

$$B_3 = A_3 \circ R_3 = (0.0366, 0.1054, 0.1276, 0.4241, 0.3063) \quad (12)$$

$$B_4 = A_4 \circ R_4 = (0.15, 0.33, 0.14, 0.31, 0.07) \quad (13)$$

So, the fuzzy comprehensive evaluation matrix R of the first layer is:

$$R = (B_1, B_2, B_3, B_4)^T \quad (14)$$

Thus comprehensive evaluation vector B of M Provincial SGC power purchasing risk is:

$$B = A \circ R = (0.0557, 0.1576, 0.1171, 0.4012, 0.2683) \quad (15)$$

Analysis of the Evaluation Results

$$d_1 = 0.0107 \times 100 + 0.132 \times 80 + 0.0875 \times 60 + 0.4519 \times 40 + 0.3179 \times 0 = 34.9569 \quad (16)$$

$$d_2 = 0.0588 \times 100 + 0.1199 \times 80 + 0.1185 \times 60 + 0.3833 \times 40 + 0.3196 \times 0 = 37.9113 \quad (17)$$

$$d_3 = 0.0366 \times 100 + 0.1054 \times 80 + 0.1276 \times 60 + 0.4241 \times 40 + 0.3063 \times 0 = 36.711 \quad (18)$$

$$d_4 = 0.15 \times 100 + 0.33 \times 80 + 0.14 \times 60 + 0.31 \times 40 + 0.07 \times 0 = 62.2 \quad (19)$$

$$d = 0.0557 \times 100 + 0.1576 \times 80 + 0.1171 \times 60 + 0.4012 \times 40 + 0.2683 \times 0 = 41.2574 \quad (20)$$

So, the primary index can be ordered as $d_4 > d_2 > d_3 > d_1$, in which the risk from government side is the largest, indicating that the government side has the most far-reaching impact on Grid Company, followed by the risk from supply side, the risk from Grid Corporation side and demand side which are minimum. Therefore, the Grid Company should consider the risk degree from demand side, supply side, SGC side and government side when making risk aversion policy.

On the whole, the electricity purchasing risk score of M Provincial Grid Company is 41.2574, very small, revealing that the risk from Grid Company is limited, thus the Grid Company should be focused on avoidance of the risk from the government side and supply side, so as to further reduce the electricity purchasing risk.

1) Analysis According to the Principle of Maximum Membership Degree

According to the principle of maximum membership degree, 0.4012 is the maximum among the five grades of membership. Therefore, the comprehensive membership degree value of the Grid Company power purchasing risk is 0.4012, and the evaluation value is "less risky", indicating that the management of power purchasing risk is well, and the risk degree is very small.

2) Analysis with Converting the Evaluation Results to Scores

Assume evaluation sets $V = \{\text{very good, good, normal, bad, very bad}\} = \{100, 80, 60, 40, 0\}$. The score of each index is:

Conclusions

Based on the identification of the Grid Company purchasing risk sources, this paper establishes comprehensive evaluation system of electricity purchasing risk, taking M Provincial Grid Company as an example to analyze its electricity purchasing situation and risk source sorting, and meanwhile, it provides reference for policymakers to make purchasing power risk identification, control and avoidance. In view of all kinds of risk from different market participants, it is feasible to reduce the size of risk by means of SGC's evasive action, risk mitigation action and the action of remaining risk and risk transfer, which has great significance on the economic and sustainable development of Grid Company.

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